Building a PCK Proposal for Primary Teacher Education in Electrostatics

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Introduction

Scientific learning implies the challenge of bridging everyday experience and scientific knowledge. Physics Education Research (PER) studies for overcoming conceptual knots in scientific learning suggest to introduce primary school pupils in science education very early, along with the first experiences of interaction with the surrounding world to develop observation and interpretation of phenomena (Michelini 2010). To motivate and promote learning in secondary school, the suggestion is to teach physics in a differentiated way according to the context in which it is applied, taking into account the different approaches, angles of attach, perspectives with which learners look at phenomena, students' spontaneous reasoning and models, learning processes. This produces a task in teacher education: PER has to support with materials and suggestions the professional development of teachers in acquiring new competencies, required by the evolution of our society: the main teachers needs are a reflection on the subject focused on learning goals, a planning of the rationale for innovative teaching/learning paths, a capability to manage learning contexts, an expertise in learning processes analysis. This implies the possibility to provide prospective teachers with the fundamentals of science education in a way allowing them to manage these elements in games, stories, questions of curious children, moments of organized analysis, adapting the subject related content and its teaching to the different perspectives of the pupils (Michelini 2003).

To reach this professionalization for teachers pre-service and in service training aims to integrate content knowledge (CK) and pedagogical knowledge (PK) in order to achieve Pedagogical Content Knowledge (PCK) (Shulman, 1986), a process during which prospective teachers must be supported in their reflections on concepts and methods for incorporating CK and PK. PER materials, as research outcomes and prototypes of teaching/learning paths, can be offered to the teachers as a support for school work planning; they can be supported in their planning and learning analysis to produce a fertile classroom environment, coherent proposals in teaching activity, attention to learning processes.

In this paper we discuss a research based formative intervention for prospective primary teachers (PPT) on electrostatics inspired by these issues.

A path on electrostatics

Electrostatics is the context where some fundamental electromagnetic concepts as charge, (electric) field and potential are introduced; moreover, as our path highlights, it offers the opportunity to deal with the concept of state, the conservation principles, the analysis of microscopic properties in systems through macroscopic phenomena. Electricity is a common topic even in primary school and a field where a broad research pointed several learning difficulties, particularly with regard to electrodynamics (Duit , 2009). This difficulties appear to be linked to difficulties in electrostatics (Benseghir & Closset 1996, Eylon & Ganiel, 1990); therefore research was carried out about the students' reasoning in interpreting simple electrostatics phenomena as electrification by friction and contact, induction and transfer of charge (Furiò et al. 2004, Guruswamy et al. 1997, Duit, & von Rhöneck, 1997). Charge emerged as conceived according to four models: entity created by friction, electric atmosphere, fluid (the most used one), charged particles; the models of charge transfer take into account only charge amounts or Coulomb force; the concept of electric potential turns out to be one of the greatest sources of learning difficulties in both electrostatics and electrodynamics. Research reveals that learning difficulties are deeply rooted in high levels of education, and poses the challenge of trying to prevent the establishment of deeply rooted reasoning rather than to change it at high age level. It is important to give students opportunities for scientific interpretation of the phenomena in parallel with their first exercises of interpretation, also to form the habit in the physics scientific method that will be a core part in education. Carrying out these activities with students involves training teachers to handle them, so it is necessary not only to fill gaps in subject content resulting from a lack of knowledge, but rather to realize the pedagogical content knowledge (PCK) that would make effective their class activities.

For this scope, focusing on the research on learning processes and on the learning problems, some validated ways of working with pupils and an educational path are produced (Mossenta 2010) and presented to PPT. The concept of charge construction is the main goal, starting from the learning and subject-related knots, in the framework of the Model of Educational Reconstruction (Duit MER-2006). The proposal is organized as a macroscopic exploration of charging processes to individuate properties and states related with a preparation of the observed system. Charge mobility and conservation are analyzed in this context. An introduction of the concept of potential linked to its role in electrostatic phenomena is carried out by means of measurements by on line sensors: the need of the potential emerges from the analysis of some processes of charge transfer, taking also into account the conservation of charge. Focused on the macroscopic properties of the electric interactions, the first part of the proposal aims to build the first level of a coherent interpretation of electrostatics phenomena (fig. 1); the second part has the methodological objective of developing the habit of looking at the experiences as involving global systems (fig. 2). The experiments were planned as starting tools for thinking in developing knowledge in electrostatics; we investigate the effect of the planned chain of experiments in producing the construction of a conservative quantity describing the state of systems, the electric charge, and how it is expressed, particularly among prospective teachers of primary school.

The hypothesis to check is that a training too focused on content rather than provide elements of knowledge produces uncertainties in the management of everyday problems that are not yet known in the training and non-standard examples. Instead, to provide specific operational tools by proposing validated ways and paths that will be experienced with a personal and direct involvement could help prospective teachers to use their teaching skills in context, identifying the value that each issue has for the students and taking the most appropriate educational decisions.

Figure 1: Experiments and materials for the first part of the proposal (Part 1)

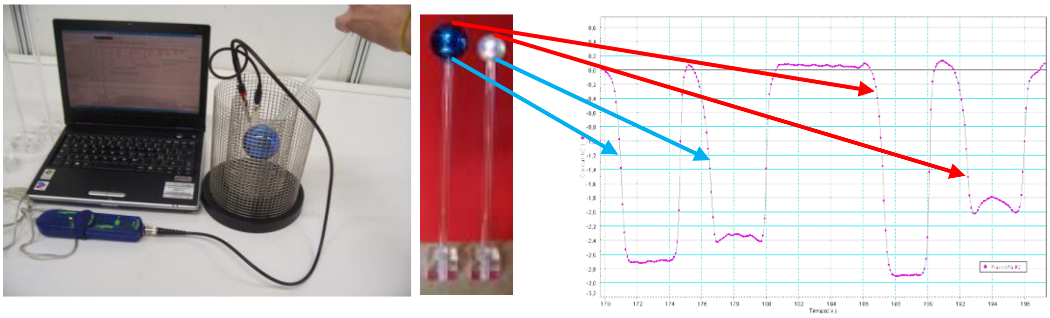

Figure 2; Experiments and measurement with a charge sensor: second part of the proposal (Part 2)

Context, sample, instruments and methods

We developed a Module of Formative Intervention (MIF) starting from the implementation of the part 1 with pupils and the consequent individuation of a coherent proposal based on Conceptual Laboratories of Operative Exploration (CLOE). A pilot study of the part 2 was carried out with high school students in the perspective of a vertical curricular proposal. The research inquiry learning based MIF was organized from Part 1 + Part 2 for PCK teacher formation. To assess the validity of the hypothesis an activity was proposed to two groups of PPT, group A and group B, NA = 64, NB = 11. The activity was on the same content (on the first part of the path in electrostatics) but implemented according different ways: presenting the proposed experimental teaching path in the first case, with a traditional treatment of the content in the second; then a questionnaire was filled in with questions similar to those already reported in the literature on charge transfer (Guruswamy et al, 1997), asking the questions in the form of identifying ways for an implementation in teaching in the first group (GA), in the form of justification of the claims in the second (GB). The path on the charge transfer was proposed and a second questionnaire was submitted to Group A, with Rogersian interviews of small group of tree PPT to complete data from questionnaire. PPT were asked to comment on the students' ideas on the same phenomena (as emerged from the literature) and to identify educational strategies to correct any identified incorrect idea. These materials provide an analysis of the conceptual change induced by the activity and of the level of expression of the activity effectiveness as regards the acquisition of both disciplinary and pedagogical skills (PCK).

The first part of the questionnaire, common to both groups in its content, proposed six situations of charge transfer: four between metal spheres of equal sizes, two between metal spheres of different sizes. In the first questionnaire students were asked for previsions about the final charge on the spheres in the different situations shown by pictures as in fig. 3 (Q1: What will be the final charge on the spheres in the different situations shown?); then students in Group A were asked about explanations for students (Q2: How would you explain your prevision to a student?) and students in Group B were asked about their own explanation.

Fig. 3: Picture in the questionnaire to ask for the transfer of charge (situation a).

The proposed situations before the contact between the spheres of the same size are:
a) Sphere A: +8 μC; sphere B: +2 μC.
b) Sphere A: +8 μC; sphere B:-2μC
c) Sphere A: +8 μC; sphere B: 0μC
d) Sphere A:-8μC; sphere B: +2 μC .
Here we analyze this part and the first item in the second part of the questionnaire of GA:
"A child says that there is a transfer between two identical metal objects until each has half of the net initial charge. Do you agree? Which ideas led the children to answer this in your opinion?"

Research questions
To make a comparison between the two ways to give to the prospective teachers PCK elements, we define the following Research questions:
RQ1: What are the students' ideas about the transfer of charge in the two groups? Are they local or global, coherent in the different situations proposed? Is it possible to distinguish between the two ways of teaching, as concerns the nature and the features of the students ideas?
RQ2: Do prospective teachers modify their own explanations taking into account the pupils perspective when requested of an explanation for children? In which way?
RQ3: What are the ideas of the prospective teachers about the processes of interpretation in pupils? Do they assume the creativity of pupils as a source to be driven by a careful interpretation of phenomena?
What strategies can be helpful in an effective activity in developing PCK?

Data and data analysis
Q1: What will be the final charge on the spheres in the different situations shown?
In situation a, where the two spheres of the same size were positively charged before their contact, the majority of students (89% of GA and 73% of GB) make a prevision of the same final quantity of charge (+5 μC) on each sphere. The other 7/64 GA students (11%) foresee an unchanged situation, explained by the repulsion between charges of the same type: "In this situation the two charges repel because have the same sign"; the other 3/11 GB students (27%) do not answer. Students in majority admit a transfer of charge between the two objects differing only in the amount of their charge; a few students reveal a reasoning according to the Coulomb's law, preventing a transfer if systems charged with the same kind of charge are involved. All answers are consistent with the conservation of charge.

Situation a: Charge before the contact: Sphere A: +8 μC; sphere B: +2 μC What will be the final charge on the spheres? ANSWERS	GA N=64	GB N=11
A: +5μC; B: +5μC.	57 (89%)	8 (73%)
A: +8μC; B: +2μC.	7 (11%)	
Not answered		3 (27%)

Table 1: Answers about the final charge on spheres in situation a before the contact: Sphere A: +8 μC; sphere B: +2 μC.

In situation b, (Sphere A: +8 μC; sphere B: -2μC before their contact), it is possible to recognize the same reasoning concerning the transfer of charge as before; moreover, a few students imagine the neutralization of the less charged sphere as the final state of the systems,

or the same number of charges on each sphere, or claim the idea of an exchange of the signs of the charges on the spheres.
56/64 (88%) students of GA and 6/11 (55%) of GB make a prevision of a net charge equal to the two spheres, with three different representations:

- 43/64 (67%) students of GA and 4/11 (36%) of the GB state a final charge of +3 μC on each sphere (b1);
- 7/64 (11%) students of GA suggest +3 μC on the sphere A, -2μC and +5 μC on the B (b2);
- 6/64 (9%) students of GA and 2/11 of GB state +4μC and -1μC on each sphere (b3).

The representations b2 and b3 are the results of different reasoning about the processes involved in the transfer of charge, the representation b1 involves one of the two previous processes and the idea of disappearing of opposite charges.
8/64 students (13%) in GA and 2/11 in GB give different predictions: relating both spheres (with the same number of charges or an exchange of the charge signs, 3 students) or looking to one sphere, that becomes neutral (3 students in GA, 1 student in GB); 3/11 students (27%) of the GB do not answer. 60/64 students (94%) in GA and 7/11 (64%) in GB give answers consistent with the conservation of charge.

Situation b: Charge before the contact: Sphere A: +8 μC; sphere B: -2 μC What will be the final charge on the spheres?		MATERA N=64	UDINE N=11
Same amount of charge on each sphere	A: +3μC; B: +3μC (b1).	43 (67%)	4 (36%)
	A: +3μC; B: -2μC & +5μC (b2).	7(9%)	
	A: +4μC & -1μC; B: +4μC & -1μC (b3).	6 (9%)	2
Neutralization of the less charged sphere	A: +6μC; B: -2μC & +2μC.	3	1
Unchanged situation	A: +8μC; B: -2μC.	2	
Same number of charges on each sphere	A: +4μC; B: -2μC & +2μC.	1	
Exchange of sign of the charge	A: -2μC; B: +4μC.	1	
	A: -8μC; B: +2μC.	1	
	A: +4μC; B: +6μC.		1
	Not answered		3 (27%)

Table 2: Answers about the final charge on spheres in situation b before the contact: Sphere A: +8 μC; sphere B: -2 μC.

In situation c (Sphere A: +8 μC; sphere B: 0μC before their contact) can be recognized the same patterns of reasoning as before. 58/64 (91%) students in GA and 5/11 (45%) in GB state an equal net charge of +4 μC on the two spheres; 5/64 students (8%) in GA and 3/11 (27%) in GB give different predictions: the situation is expected to be unchanged (2 students in GA and 1 in GB), "The sphere B hasn't got charge and doesn't take anything from A" (GA); the spheres are expected to be charged of the same amount of the two kinds of charge, "by induction": +4 μC on the sphere A and -4μC on the B (1 student in GA and 1 in GB); +8 μC on the sphere A and -8μC on the B (1 student in GA); finally, the states of the sphere are exchanged for a total transfer of charge, 0μC on the sphere A and +4 μC on the B (1 student in GA), 0μC on the sphere A and +8 μC on the B (1 student in GB). 1 student of GA and 3 in

GB do not answered. 60/64 students (94%) in GA and 6/11 (55%) in GB give answers consistent with the conservation of charge.

Situation c: Charge before the contact: Sphere A: +8 μC; sphere B: 0 μC What will be the final charge on the spheres? ANSWERS	GB	UDINE N=11
A: +4μC; B: +4μC.	58 (91%)	5 (45%)
A: +8μC; B: 0μC.	2	1
A: +4μC; B: -4μC	1	1
A: +8μC; B: -8μC.	1	
A: 0μC; B: +4μC.	1	
A: 0μC; B: +8μC.		1
Not answered	1	3 (27%)

Table 3: Answers about the final charge on spheres in situation c before the contact: Sphere A: +8 μC; sphere B: 0 μC.

Q2 (GA only): How would you explain your prevision to a student?

Situation a). As regards the explanation that the 57 prospective teachers stating a final charge of +5 μC on each sphere would pose to the pupils, 44/57 students explain identifying a final state of the system of the spheres corresponding to the configuration of charge reported (category A); 8/57 express only a process that does not need the idea of final state (category B). 37/57 students in both categories explain describing a process. The majority of explanations involves the macroscopic systems of the spheres as acting entities. The state expressed in category A can be equilibrium, without explaining the meaning of this concept, (A1) or the same number of charges (A2). The majority (37/57 students, category A1) of students explain the prevision as corresponding to a state of equilibrium to be reached: of these 37 students, 26 (Category A1.1) describe a process that leads from the initial state to the final state of equilibrium: for 25 students it is a transfer, for 1 a distribution: "nothing happens because like charges repel; brought towards a forcing, the charges realized a distribution balancing each other". A total of 21 students would explain referring to an action of the spheres (the sphere more charged sales/transfers charge), 4 of the charge (the charge moves "to achieve an equilibrium") and 1 student does not introduce an agent ("there was a transfer of charge from A to B reaching an equilibrium of charges"). 11 students (Category A1.2) indicate only the correspondence between the configuration written in the previous answer and the equilibrium, in the form of a final state: reached by the spheres ("the two spheres reach a state of equilibrium", 9 students), or by the charges (1 student: "charges will balance”), or after the contact (1 student "as the ball has a smaller number of +, the contact will make to achieve an equilibrium between the charges"). 7 students (Category A2) indicate the final state as corresponding to the same number of charges (amount of charge) on each sphere: 5 (Category A2.2) state it without indication of a process leading to this state: 2 consider it an aim of the spheres (“the spheres want to achieve the same number of charges”) and 3 describe it as a situation resulting from the contact: "after the two spheres touched there will be the same number of positive charges”. 2 other students (Category A2.1) consider the same number of charges as a final result: of the process of charge transfer or of the process of cession by the more charged sphere. 8 students (Category B) do not indicate a final state but identify a process able to account for the result: it is an equitably distribution of charges (4 students), a collection and sharing in an equal way of the charges by the balls (3), a situation described step by step without specifying the subject of actions: after the contact there is an amount of charges then divided into the two spheres (1). 1 student indicates only the transfer of charge from the sphere more charged, thus providing an explanation not exhaustive for the situation stated before. 2 students do not explain, 2 students give an explanation inconsistent with the situation stated for the spheres: it is the same explanation given by the 7 students who state a final situation unchanged, as there will not be transfer because of the repulsion between like charges (knot already noted in the literature, Guruswamy et al, 1997).

ITEM A EXPLAINATION STRUCTURE	PREVISION: A: +5µC; B: +5µC; How would you explain your prevision to a student? CONTENT	NUMBER OF ANSWERS
FINAL STATE 16 (25%)	CHARGE EQUILIBRIUM "Spheres want to reach a charge equilibrium"	11
	SAME AMOUNT OF CHARGE "After the spheres touched there will be the same number of positive charge"	5
FINAL STATE AND PROCESS TO REACH IT 28 (44%)	TRANSFER OF CHARGE TO REACH EQUILIBRIUM "The sphere A, more charged, transfers a part of its charge to the sphere B, creating a charge equilibrium"	25
	TRANSFER OF CHARGE TO REACH THE SAME AMOUNT "The sphere A wanted to transfer some charges to the sphere B to reach the same charge"	2
	CHARGE DISTRIBUTION MAKING EQUILIBRIUM "Charges spread making each other equilibrium"	1
PROCESS ACCOUNTING FOR THE PREVISION 8 (13%)	EQUAL DISTRIBUTION OF CHARGE "The two spheres touch and the positive charges realize an equal distribution"	4
	CHARGE COLLECTION AND THEN SHARING OUT "The two spheres collected all charges and then shared out them equally between themselves"	4
PARTIAL EXPLAINATION	TRANSFER OF CHARGE FROM A TO B	1
NO COSISTENCY (3%)	"In this situation the two spheres have the same kind of charge, so they cannot touch/repel"	2
NOT ANS. (3%)		2

Table 4: answers about the explanation for pupils in situation a: prevision of a final situation with the same amount of charge on each sphere

Situations b, c, d. The analysis of the answers for the situation b, c, d, shows that among the 26 students in the category A1.1, 24 students show consistent answers in situations b and d (which differed only in the signs of the charges on the spheres). 21 students converge towards a model that explains the prediction concerning the final charge on the spheres as a sale/transfer by the spheres (as they did in situation a, now adding the idea of cancelling of opposite charges), but whit differences: 18 students refer to a one- way transfer by the sphere ("the two spheres, after they touched, reach an equilibrium state generated by the fact that two charges are cancelled and 3 charges are transferred to the sphere B"), and 4 express a two-ways transfer: "to achieve an equilibrium between the two spheres the sphere B transfers a charge – to the sphere A and in turn the sphere A will transfer 4 charges + to the sphere B. So we will have that the charge - that there is in both spheres cancel a +, then you will have in the sphere A 3 charges + and 3 charges in the sphere B". 2 students consider for the situations b/d that there will be a transfer until the neutralization of the less charged sphere ("Touching the spheres, the sphere B takes 2 positive charges from the sphere A and becomes neutral"), and an unchanged situation c for the neutrality of one of the two spheres ("The sphere B has no charge and takes nothing from the sphere A and so it remains neutral"). 3 other students of the category A1.2 take the wording b3 (1 of them explains with a process where the sphere A gives to B and takes from it charges), 1 the b2 (explained with a transfer for the equilibrium without introducing the idea of neutralization) and 7 the b1: 2 of them express a process. For

5/7 students of category A2, equilibrium is identified with the same number of charges, and two other students introduce processes to explain, besides the two who already had made it in the situation a. One of the students maintaining the explanation based on the same number of charges images for the situation b a charge of +4μC on the sphere A, -2μC and +2μC on the sphere B, explaining: “the spheres want to reach the same number of charges, or elements” without taking into account both the effect of neutralization and the conservation of charge. In situation d this student introduces a kind of mathematical procedure: “making the algebraic sum the number of charges equals”. Among the 8 students in the group B, 5 maintain the models expressed in situation a, 1 does not provide an explanation, 2 give inconsistent answers, the 3 who had thought of a distribution charges in the situation a report the same model in the following situations (1 does not provide explanation), 2 among the of 4 who had looked at a collection and sharing by the two spheres in the situation a mostly use the same model (shifted to a transfer in case c), 2 give inconsistent answers, like the rest of the 9 students who in situation a predicted a situation unchanged (6 of them explain with a transfer to reach equilibrium the situations b and d, with a distribution the situation a) or gave inconsistent answers.
10/64 students (16%) express their explanations using explicit expressions of intention, obligation, desire, characterizing in an animistic way the behavior of physical entities: in 8 cases, these explanations claim only final states of the spheres, "the spheres want to achieve equilibrium" in 2 cases the explanation is a description of a process. A lower level of animism can also be seen in the feature of the spheres or the charges of making actions, as sale or transfer, reported by most students.

Explanation of predictions in GB

In Group B, answers related to the same final amount of charge on each sphere are explained with processes as in Group A: for some students (attractive) forces are the starting point for the transfer, in some cases the idea of equilibrium is expressed only in situation a and not transferred in the other situations where the systems are not seen in the same condition of charge after their contact. 2/11 students explain their predictions in situations a and c with a charge transfer process to reach equilibrium, "the charge passes from the more charged sphere to the less charged until the two balance each other"; this transfer becomes a two-ways transfer in situations b and d, to reach a final state of +4 μC and -1μC in situation b (with reversed signs in the situation d). Other 2/11 students express the same processes but connect them to the attractive interaction between charges in situations b and d: “The spheres have opposite sign, so they attract, there is a direct interaction and they exchange charges”. Situation a highlights in one of these answers the learning problems related to the concept of interaction: "The sphere A gives some charges to the sphere B that B acquires and there is an interaction in both directions". In situation a other 2 students refer to a final state that the spheres must reach: in 1 case it is the equilibrium, in 1 it is undefined: "achieving a similar state"; 1 other student explains through a process of distribution: "on the two spheres the same amount of charge distributes". These 3 students in the remaining situations, not always complete, express previsions of different final charges on the two spheres, with explanations based on the greater influence of more charged sphere (2 students), or without explaining. 3/11 students do not answer at all. Answers in GA are more coherent across the different proposed situations than answers in GB; the processes expressed are the same, but some students in GB cannot find an explanation at all.

Second part of the questionnaire (GA)

The first question in the second part of the questionnaire asked students (N=61) for a discussion about a pupil’ claim when asked about the transfer:

A child says that there is a transfer between two identical metal objects until each has half of the net initial charge. Do you agree? Which ideas led the child to answer this in your opinion?
Q1: Do you agree?
51/61 students agree with the proposed claim, 7/61 do not agree, 3/61 did not answered.
Q2: Which ideas led the child to answer this in your opinion?
14/61 (23%) students see in the pupil's answer the same process they imagine to use as explanation (equally divided into transfer "Charges transfer until the spheres are equally charged, cancelling 2 charges" and spread out "Charges spread out equally, with a cancelling of two positive charges by the two negative charges"); 14/61 report that pupils have the idea of final state, justified (differently from their explanations) by the features of the observed system (equal size of the spheres: "Spheres with an equal diameter will reach equilibrium" "Equal spheres suggest the idea of equal charges"); 9/61 (15%) students say that pupils find their idea as a possibility validated by the final state of equilibrium, as a constrain for the system "Because in this manner there will be an equilibrium between spheres"; 12/61 (20%) claim that children think according mathematical procedures "He takes 2 from 8 and obtains 6 and then divides equally", 2 students think that pupils can answer in this way because they know the issue "Because the child knows that if two bodies with different charges are in contact an equilibrium between charges are created". The answers "no" aims to give to the children a model different from transfer; 2 students wrote only the ideas of children: one, a process; the other a mathematical procedure.

Discussion
In all cases the GB students show greater difficulty responding than GA students (27% cannot make predictions on the final state): they seem to be blocked. The learning problems arisen in the largest group are also found in the smaller group; mostly they are the learning difficulties / misconceptions highlighted in the literature. Traditional treatment of the contents (even if very good and rigorous) does not seem to help students' reasoning, in GB: the students of this group show difficulties in connecting theory and the proposed simple new situations. The explanations are almost always written in the same way in the groups, although in the GA students were asked how to explain the topic to children: teachers tend to propose to their students the theoretical formulation they learned during their instruction, or their explanation; alternatively, they use terms bringing to mind animism of entities/objects and fairy-tale narrative ways in introducing the processes. In Group A explanations are mostly referred to a process and to states, and this feature increases examining more than one situation. A minority of students gives explanations taking into account the Coulomb force applied to the charges on the spheres as they were single point-like charges instead of groups of charges interacting. A few students use terms as "induction" giving them an explicatory value, without a real understanding of their meaning. On the contrary, two ideas drive their explanations, one explicit, equilibrium as an aim, an habit, and the conservation of charge. When asked about the pupils' ideas, some students admit that pupils can relate (but only for similarities) features of the observed systems and state of charge; others refer that the pupils' ideas are related to a mathematical procedure not supported by reasoning.

Conclusions
The way to teach prospective primary teachers (PPT) by proposing a subject related content knowledge does not provide them of better tools more than a discussion that brings out the same concepts from simple experiments designed after a reconstruction of the pedagogical content perspective (MER).
PPT invent simple models when they put themselves in teaching perspective. This models are often local, not coherent, different for different situations. PPT suggest explanations based on

a final goal that systems have (a state, not explicit), but they do not pay attention to the meaning that students attribute to the concepts (equilibrium, assumed to have a unique meaning and not described) or to the multiple interpretations. The different processes individuated in reaching the goal are possible freedom dimension of the processes. The conservation of charge, employed in explanations in an implicit way, is not recognized as a constraint that can help in selecting the final states and the processes admitted: an opportunity to support reasoning to be recognized.

When asked about students' ideas, PPT attributed to the pupils math procedures instead of reasoning and propose their invented models to enrich their ideas: there is a need of qualitative reasoning both as personal explanations and as teaching tool.

If the sentence of the student is considered wrong PPT refuse the model or suggest a procedure: they suggest the idea of the possibility of one way only for interpreting situations, or prefer the product (the value obtained whit a mathematical procedure).

In the second part of the questionnaire the idea of equilibrium is not more only a goal but become a condition for individuating the final state of the observed systems: it expresses the need of a driver for equilibrium: the idea of potential as a quantity regulating the process of charge exchange.

We argue that a macroscopic approach (as the one proposed to PPT) is useful to see how we can infer information on micro-world from phenomena analysis. Emerges that to explain changes is a fertile task to recognize states and processes, and relevant quantities for the interpretation. In this context there are critical situation that are fertile for conceptual discussion and for clarification of some crucial concepts as potential. As concerns the pedagogical approach in building formal thinking, emerges that the link between CK and PK cannot be leaved solely to PPT: an important support in analysis of reasoning and micro-level planning have to be given to the students. Searching for a rationale for the discussion of the concepts is an important task both in teacher formation and in planning school activities.

References

Benseghir A. & Closset J.L., 1996, The electrostatics – electrokinetics transition. Historical and educational difficulties, International Journal of Science Education, 18 (2) 179 -191

Eylon B. & Ganiel U., 1990, Macro – micro relationship: the missing link between electrostatics and electrodynamics in students' reasoning, International Journal of Science Education, 12 (1) 79 -94

Duit, R. (2009). Bibliography STCSE – Teachers' and Students' Conceptions and Science Education. Kiel, Germany: IPN – Leibniz Institute for Science Education (http://www.ipn.uni-kiel.de/aktuell/stcse/stcse.html)

Duit, R., & von Rhöneck, C, Learning and understanding key concepts of electricity, from Connecting Research in Physics Education with Teacher Education, edited by Tiberghien, A., Jossem, E.L., and Barojas, J, 1997,1998 I.C.P.E.

Duit R., 2006, Science Education Research - An Indispensable Prerequisite for Improving Instructional Practice, ESERA Summer School, Braga, (2006) at http://www.naturfagsenteret.no/esera/summerschool2006.html.

Furió, C., Guisasola, J. & Almudì, J. M. 2004, Canadian Journal of Science, Mathematics and technology education, 4 (3) 291 - 313

Guruswamy, C., Somers, M. D. & Hussey, R. G., 1997, Physics Education, 32 (2) 91 – 96

Shulman L. S. 1986 Educational Researcher, 15(2) 4

Michelini M, ed. 2003, *Quality Developrnent in the Teacher Education and Training,* Girep book of selected papers, Forum, Udine [ISBN 88-8420-158-6]

Michelini M, 2010, *Building bridges between common sense ideas and a physics description of phenomena to develop formal thinking,* New Trends in *Science and Technology Education.* Selected Paper, vol. 1, eds. L.Menabue and G.Santoro, CLUEB, Bologna 2010, ISBN 978-88-491-3392-9, p.257-274

Mossenta A, Michelini M, *Conservation of Charge to understand potential using on-line charge measurements,* in *Multimedia in Physics Teaching and Learning,* Michelini M, Lambourne R, Mathelisch L eds, SIF, Bologna 2010 and in Il Nuovo Cimento, 33 C, 3, 2010 NIFCAS 33(3) 1-238 (2010) (DOI 10.13932/ncc/i2010-10620-3) NIFCAS 33(3) 1-238 (2010) [ISSN 2037-4909] p.205